Coastal Engineering Technical Note

RECOMMENDED PHYSICAL DATA COLLECTION PROGRAM FOR
BEACH NOURISHMENT PROJECTS

PURPOSE: To provide guidance for physical data collection of beach nourishment projects and a listing of the components that should be included in a complete pre- and post-fill monitoring program. Project performance monitoring is needed to provide data to improve design, document project behavior and determine if project has met design objectives of storm protection and erosion control. Improvements in design guidance have been hindered by lack of performance data. Critics have declared projects failures and little or no evidence exists on project performance to counter their arguments.

BACKGROUND: Beach nourishment and sand by-passing have become widely accepted methods for storm flood control protection along the nation's coastlines. This CETN focuses on development of a monitoring plan to collect pre-project design data, and evaluate post-construction project performance, renourishment intervals and fill quantities. All of the tasks suggested here should be considered in the selection of a complete monitoring program, however each project has unique settings and all of the guidance listed may not be applicable. Standardized procedures and techniques in project monitoring are presented for guidance in evaluation of fill placement design techniques, project behavior assessment, and environmental impacts. The monitoring plan is divided into six task areas:

I. Analysis of Geologic Setting
II. The Fill Placement Area
III. The Borrow Area
IV. Shoreline Change
V. Biological Impact Assessment
VI. Littoral Environmental Assessment

A description of each task follows.

Task I - ANALYSIS OF GEOLOGICAL SETTING

A review of the geologic setting of the project area, to identify the geologic configuration and determine any geologic control on the coastal processes and shoreline setting of the area, is an important first step in developing a monitoring plan. The coast has been under the influence of dynamic processes in the geologic past, which will play an important role in present sediment distributions and regional geomorphology. The shoreline may vary in the study area with geologic parameters such as an old outflow river channel, the presence of coastal cliffs, overwash areas, inlets, and/or rock reefs. The borrow material can be from several sources which will influence its composition. An examination of the regional geology will provide valuable information on processes and monitoring considerations. A review of the geologic literature, shoreline change maps, coastal morphology, influence of

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geologic literature, shoreline change maps, coastal morphology, influence of existing coastal erosion control and navigation structures on shoreline, and coastal processes information for the project area will aid in interpretation of the influence of geologic setting on project behavior.

Task II - FILL PLACEMENT MONITORING

Beach Profile Sampling Components

Monitoring of a beach fill project includes the collection of beach profile surveys at selected intervals before and after 1) initial fill placement and 2) subsequent maintenance fill placement. Survey location selection should include profiles within the project limits and control profiles some distance up and down drift of the project boundaries and be shown in a site plan map. Specific profile survey site selection depends on type of project. Some typical beach fill project geometries are as follows:

1. Beach fill adjacent to inlet jetty,
2. Beach fill on continuous shoreline,
3. Beach fill associated with other shore protection structures,
4. Sand bypass project to downdrift shoreline,
5. Sand bypass project to updrift shoreline,
6. Sand bypass project to both updrift and downdrift shorelines.

Profile survey locations within the fill area depends on length of fill and proximity to inlet or shore normal structures. Actual distances to be used are site specific and need to cover all areas of the fill placement. Profile spacing is controlled by degree of longshore variability with 100 to 1000 ft intervals for detailed coverage (ie. near groins, inlet jetties or complex beach and nearshore morphology) and distances up to 1/2 mile for long, straight, homogeneous fills. Cost factors require that the minimum number of profiles be collected which will adequately characterize all aspects of the fill area.

A minimum of one control profile located at least one mile updrift and downdrift of the project limits should be monitored to compare behavior of the fill with natural beach profile changes and assess the impact of longshore movement of fill. In areas of suspected high rates of alongshore sediment transport, additional control profiles may be required along the beach in the predominant drift direction. Seasonal drift reversals may require more control profiles on both sides of a project. If a project is near an inlet or is an inlet sand bypass project, profiles updrift and downdrift of the inlet should be monitored to assess fill movement relative to inlet processes. A higher density of profiles should be located around proposed nearshore fill deposition areas where fill is not placed directly on the berm but is placed in a low tide to nearshore location, in anticipation of documenting more subtle morphology changes.

Profile surveys should be taken from known benchmarks that are documented and relocatable in future years. Permanent control points prove useful for relocating benchmarks after extreme events, such as was the case for Hurricane Hugo. The sub-aerial portion of the survey should extend from a

stable point on the beach (behind dune crest, seawall or bluff line) and extend on a repeatable azimuth normal to the shoreline as far as possible into the water (ie. wading depth). Surveying around the time of low tide provides the maximum exposed beachface area. The offshore portion of the survey should be taken at the same time as the land portion of the profile preferably with a sled using a total station (see Clausner, Birkemeier and Clark, 1986). The recommended frequency for survey profiles is listed in table 1 to assess changes in the profile from the backbeach area (ie. limit of storm runup at dune, seawall) seaward to depth of closure. If a fathometer is used in place of a sled, care must be taken to record date, time, wave conditions and

Table 1. Example of Beach Fill Area Profile Survey Scheme.

Year	Times/year	Number of Profiles
pre-	2	Collect within fill and control profiles in summer and winter months to characterize seasonal profile envelope (beach & offshore)
post-	1	Collect all profiles immediately after fill placement completion at each site (beach & offshore) to document fill placement volume, collect control profiles immediately after project is completed
1	4	Four quarterly survey trips collecting all beach and offshore profiles out to depth of closure Quarterly surveys start the quarter after post-survey
Continue year 1 schedule to time of renourishment (usually 4-6 years)		
If project is single nourishment event taper surveys in out years:		
2	2	6 and 12 month survey of all beach and offshore profiles
3	2	6 and 12 month survey of all beach and offshore profiles
4	1	12 month survey of beach and offshore profiles

Note:
* If project is renourished, repeat survey schedule from post-fill immediately after each renourishment to document new fill quantity and behavior.
* Special profile surveys should be conducted subsequent to major storm events.
* Project specific morphology and process requirements may modify this scheme.
* Monitoring fill after major storm events is highly desirable to assess fill behavior and storm protection ability. Include profile and sediment sampling and take less than one week after storm conditions abate to document the response to storm processes.

position of fathometer relative to water level datum for latter correction and correlation with land based profile surveys. Wading depth profiles are surveyed at low tide and the offshore fathometer survey is done at the next high tide, allowing for some overlap between the two to match for a continuous profile. Both the subaerial and offshore portions of the surveys must be collected as close to the same day as possible during every data collection period to reduce possible error in matching profiles collected during different conditions.

Beach Sediment Sampling Components

Sediment samples should be collected during each profile survey, at a minimum of three sample locations (Mean High Water - MHW, Mid-Tide level - MTL and Mean Low Water -MLW) per profile line. Additional sampling locations at step (where the backwash meets the incoming bore), bar trough, bar crest and at 5 ft intervals to depth of closure is desirable to characterize the variation in cross-shore sediment distribution along the entire active profile. To characterize the pre-fill native beach, short cores should be collected (at selected locations on selected profile lines). While detailed core sampling locations are determined on a project specific basis, along-project zones of mid-berm, berm-crest, mid-tide and step should be adequately sampled. Core sampling will identify variability in native beach seasonal and storm related sediment distribution. Shallow cores (about 2 ft long) will penetrate both the present deposition and, on most beaches, the envelope of past seasonal deposition. Longer cores may be necessary on beaches with a large envelope of seasonal change. This envelope of seasonal change can be determined by looking at historical profiles that cover several seasonal conditions. If cores are not taken, an alternate method is to collect surface samples at the specified locations, during a summer and again during a winter period, before the project is constructed. Analysis of this one time stratigraphic data or temporal data will identify the seasonal variability in sediment distribution, to give a clear picture of the native beach sediment characteristics for fill suitability calculations.

Sediment redistribution across the entire profile should be monitored during the time of beach and offshore profile surveying during all post-construction survey periods. Sediment samples do not need to be collected at every profile, but a minimum spacing between profiles where sediment samples are collected should be 1/2 mile. By collecting shallow grab samples of approximately 100 g, sampling characterizes the hydrodynamic zonation of the sediment grain size distribution as the fill material readjusts to the coastal processes, rather than the more common practice of sampling at fixed distances seaward of a shore reference point regardless of profile shape and swash zone position. Spatial and temporal distributions of sediment sampling are listed in Table 2.

Fill Placement Area Data Analysis

Data analysis should include profile volume change and shape readjustment, area of loss or gain on profile, volume of fill remaining on project, assessment of alongshore and cross shore fill movement from beach and

Table 2. Example of Beach Fill Area Sediment Sampling Scheme.

Year	Times/year	Number of Samples
pre-	1	Cores (2 times if surface samples) to characterize native sediment at time of beach & offshore profile collection and seasonal variation.
post-	1	Surface samples taken immediately after fill placement to characterize fill material during beach & offshore profile collection.
1	4	quarterly - collect surface samples over entire length of profile during time of each beach and offshore profile collection. Minimum spacing between profiles should be 1/2 mile. Quarterly surveys start the quarter after post-survey
Continue year 1 schedule to time of renourishment		
If project is single nourishment event taper sampling in out years:		
2	2	6 and 12 mo - collect subaerial and subaqueous surface samples during beach and offshore profile collection.
3	2	6 and 12 mo - collect subaerial and subaqueous surface samples during beach and offshore profile collection.
4	1	12 mo - collect subaerial and subaqueous surface samples during beach and offshore profile collection.

Note: * If project is renourished, repeat the schedule above beginning with post-fill plan immediately after fill placement to document new fill sediment characteristics.
* Project specific conditions may modify scheme.

nearshore fill placement area, and seasonal and storm response. Sediment analysis will include grain size statistics of native and fill material, with readjustment over the monitoring period, seasonal and storm grain size response, and assessment of fill and renourishment factors for future fill requirements (Stauble and Holem, 1991).

Report writing should summarize behavior and response of the beach fill to local and regional coastal and geomorphic processes.

Task III - BORROW AREA

There are several categories of borrow areas used for beach nourishment projects. Monitoring of the borrow area will depend on the category, but assessment of fill suitability and borrow site infilling rates and reusability

are the main goals of this monitoring task. Biological monitoring of the borrow area may also be required. Borrow area types include:

1. Offshore
2. Inlet shoals - either flood or ebb tidal deltas
3. Sand traps
4. Bay or lagoon areas
5. Upland sources

The location and number of cores and seismic survey tracks required will depend on the type and number of borrow area used. Selection is on a case-by-case basis but should be sufficient to characterize the boundaries and a regular spacing within the proposed borrow area. Anders and Hansen (1990) suggest a minimum of 1 core/1,300,000 ft^2 (29.8 acres) for potential borrow sites and 1 core/15,000,000 ft^2 (344 acres) for exploratory siting. A control area outside the borrow should be used to characterize the sediment and infauna changes in the natural bottom. For more details on borrow area sampling see Meisburger (1990).

<u>Bottom and Sub-bottom Survey</u>

For all marine borrow areas, a boat and crew will be needed to perform seismic surveys and support vibracore operations. Bathymetric and sub-bottom surveys using bottom penetrating acoustic device are needed to locate suitable borrow areas in conjunction with vibracores. Seismic surveys are done first for identification of the areal extent and depth of usable borrow material. The location of cores is determined from studying the seismic records. Location and extent of layers of unsuitable material are needed during pre-dredging exploration. Sand layers are often discontinuous or contain lenses of unsuitable fine grained silt and clay material that cannot be discerned by surface sampling alone. Bathymetric surveys after dredging and during the last year of monitoring are desirable to examine borrow area infilling.

<u>Borrow Area Sediment Sampling</u>

Borrow area study should include collection of cores before dredging to support biological monitoring and for assessment of fill suitability. Surface samples should be collected immediately after dredging to document the post-dredged borrow area. These tasks need to be coordinated with a biologist for concurrent collection, if environmental monitoring is required. During the last year of monitoring, cores should be collected in the borrow area of the depositional basin. Sampling should include one control site outside of the immediate borrow pit to document natural changes that occur over the life of the project. Table 3 provides a recommended schedule for borrow area sampling.

<u>Data Analysis of Borrow Area</u>

At least three sediment samples (top, middle, and bottom) should be taken per pre-dredging core (should average 20 ft long) to assess the sediment suitability of the entire borrow area. The exact number and location of samples within each core depends on the complexity of the sediment types and layering, but a representative sample should be taken from the top layer, and

Table 3. Example of Borrow Area Sediment and Seismic Sampling Scheme.

Year	Times/year	Number of Samples
pre-	1	Bathymetry and sub-bottom profile of pre-dredged borrow site(s) and nearby control area. Cores to characterize borrow material and control areas to assess fill suitability.
post-	1	Surface sediment grab samples to characterize post-dredging borrow area sediment distribution. (for biological study - see next section) Bathymetry of post dredged surface to assess volume of fill dredged.
last	1	Surface samples to characterize infilling sediment for possible reuse as fill. Bathymetry of borrow area to assess infilling volumes.

Note: * Seismic track line and core number and locations are site dependent.

each distinct change in lithology should be analyzed to characterize the entire depth of dredging. An alternative method is to channel sample the entire length of the core (Anders and Hansen, 1990). This sampling will also be coordinated with biological sampling of the borrow area. All lab analysis and operations on cores should be standardized as to description of sediment type and grain size distribution data. Core logs with descriptions of sediment layers should be compiled and photographs of the cores should be taken to document suitable sand layers.

Data analysis should include sediment statistics in tabular and graphic form for sediment fill suitability, borrow area sedimentology to support biological analysis and usability of borrow area for future projects. Analysis of bathymetric and seismic surveys provide spatial distribution of suitable borrow areas and calculation of usable volumes of dredge material (see Anders and Hansen, 1990; Meisburger, 1990). Pre- and post-construction analysis provides temporal changes in borrow areas, calculation of infilling rates and availability for future project requirements.

Report writing evaluates the pre-dredging borrow area suitability and conditions. Post-dredging evaluation of the borrow area, and determination of the rate of borrow area infilling can be provided.

Task IV - SHORELINE CHANGE

Aerial photography overflights of the project area should be done at specific intervals as listed in table 4. These photographs can be used for construction of a base map depicting shoreline change throughout the project period. Coverage should be a single flightline with 60% overlap stereo coverage of the entire project area shoreline, including control profile

locations one mile north and south of project limits. Color infrared film with a 9x9 inch film format should be specified. The scale of the photographs should be sufficient to identify shoreline features. A scale of 1" = 400' is recommended for the base map and aerial photography. All photography should be taken around low tide, to provide the maximum area of exposed intertidal beach and inlet shoals. Proposed aerial flight times during the project monitoring are listed in table 4 and should be coordinated to occur during ground surveys. If a project includes renourishment, overflights should follow the post-fill schedule after each renourishment.

Table 4. Example of Aerial Photography Overflight Schedule.

Year	Times/year	Comments
pre-	1	
post-	1	
1	4	Quarterly overflights start the quarter after post-fill overflight
Continue year 1 schedule to time of renourishment		
If project is single nourishment event taper overflights in out years:		
2	2	
3	2	
4	1	

Shoreline Change Data Analysis

Data analysis should include shoreline changes and profile changes from pre- and immediate post-construction, and bi-annually thereafter to cover post-maintenance dredging. Products provided will be tables and maps on shoreline change rates and volume calculations of fill remaining at each flight time (Stauble, et al., 1983). The reporting of such data will augment the ground data base of historic shorelines and inlet shoaling to determine the readjusted rates of accretion and erosion along the project and control area shoreline and changes to the borrow area (particularly in sand bypassing projects showing inlet shoal and dredged basin area changes). The use of aerial photography, augmented by fewer ground profile surveys than normally are taken can provide a means to document the entire beach fill project behavior and response with a reduction in cost and time.

Part V - BIOLOGICAL ASSESSMENT

Biological surveys of both beach and borrow areas may be required for

assessment of project impact on the environment. Monitoring is often done to assess impact of dredging on the infauna, seagrasses, reefs or hardbottoms, or other biologically sensitive environments in the vicinity of borrow sites. The beach in the vicinity of the fill may also have environmentally sensitive areas resulting from sea turtle nesting, bird nesting, beach infauna and nearshore reefs. Measurements of changes in project-related turbidity levels, that may effect some organisms, may be required by environmental agencies.

Biological Sampling

Field collection consists of grab samples, and bottom trawls offshore and quadrate grab sampling and beach seine of beach areas to assess the presence of infauna and bottom feeding fish (Benthic Resources Analysis Technique - BRAT). Avoidance or relocation of turtle or bird nesting areas might be necessary in the fill placement area. Turbidity monitoring in the borrow area and along the surf zone may be required to assess project impacts on water quality during dredging operations. Surface and bottom water sampling and laboratory analysis of pre-, during project and post-construction time periods using a turbidity meter may be required to assess both background and project turbidity.

Biological Impact Assessment

Data analysis will evaluate changes in flora and fauna located in the beach fill and nearshore fill deposition area, effects of turbidity on fauna of the beach and borrow area, and the effects of dredging activities on borrow area organisms. Reports should describe and quantify the changes to or the reestablishment of the biological community in the fill placement area and borrow and compare to control sites. Turtle nesting, bird nesting and reef damage are examples of reasons for requiring biological monitoring. More information on details of biological monitoring can be found in Naqvi and Pullen (1982) and Nelson and Pullen (1985).

Part VI - LITTORAL ENVIRONMENT MONITORING

Physical processes such as waves, tides, longshore transport, wind, and storms play an important role in shaping the natural coastal environment. When fill is placed on a beach or borrow material is removed from a marine area, the system is temporarily forced into a state of disequilibrium. The coastal processes will interact with and modify both the fill or borrow area until a condition of dynamic equilibrium is reestablished. A large volume of fill material placed on a beach or a large volume of dredged material removed from the borrow area may change the physical parameters or respond adversely to the prevailing coastal processes or extreme events.

Data Collection

Wave, longshore current, and meteorological data should be examined to understand the coastal processes that occur in the project area. It is recommended that collection of wave data be an integral part of any evaluation of a coastal engineering project. Wave driven coastal processes are a

controlling factor in the response of the native and nourished beach. Wave climate characterization using hindcast data such as the wave information system (WIS) gives averaged long term conditions and can be used in project design. Actual performance of a given fill however, is the response to specific short-term events. Major profile and sediment changes can be expected during the fill placement and monitoring period as the fill material readjusts to the local wave climate. Establishing a cause and effect relationship between the actual waves and project response is essential to predict future fill behavior and to evaluate fill longevity. Documentation by deploying a directional wave gage on site will provide site-specific data that can be used to assess the movement of the fill in the cross-shore and downdrift directions. Comparison of profile volume changes and sediment resorting can be compared on a temporal bases with the wave records to identify events that affect movement of fill from the beachface to the nearshore. The magnitude of the event and the fill response can be quantified for future renourishment needs.

The methods used and resources expended for this data collection should be commensurate with project specific factors such as fill size and anticipated renourishment interval. Wave data collection should be tied to anticipated uses of that data. For example, a large project with frequent anticipated renourishment needs may benefit from post-fill monitoring of directional wave, profile survey, sediment and shoreline change data to better refine the renourishment computations and improve project design before the next anticipated fill placement. At the least, a systematic Littoral Environment Observation (LEO) program (Schneider, 1981; Szuwalski, 1986) will supply important backup information on magnitude and frequency of extreme events to analyze project performance between survey periods. This information should be collected before project construction and continue until completion of the monitoring program.

Coastal Processes Data Analysis

In order to improve our ability to design projects and have them provide the desired flood control and storm damage reduction benefits, data need to be collected and analyzed in a systematic manner. Coastal processes data need to be compared to project behavior data and the results applied to improved design templates. The link between fill volume change and the forcing functions of wind waves, tides and currents can be accomplished by time series plots of profile volume and sediment grain size with significant wave height, peak period, water levels, and current magnitude and direction plots. Identification of critical values of each coastal process can be correlated with erosion volumes and sediment depositional patterns. This data can then be applied to design parameters for future project application.

With increasing costs and stringent regulations on project impact, monitoring must become a required part of any project, with an ultimate goal of improved design for increased project longevity. Table 5 summarizes the overall monitoring schedule for projects that have renourishment scheduled on a continuous basis (ie. sand bypass) and for projects that will be renourished at long term intervals (ie. greater than four years between fill placement events). Additional details on beach nourishment monitoring can be found in

Stauble and Hoe1 (1986) and Stauble (1988). Size, location, frequency, and placement methods are all variables that can be optimized for renourishment with proper use of monitoring data.

ADDITIONAL INFORMATION: For additional information contact Dr. Andrew Morang of the Coastal and Hydraulics Laboratory at (601) 634-2064, Andrew.Morang@erdc.usace.army.mil.

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Table 5
SAMPLING SCHEDULE FOR BEACH FILL MONITORING
(For projects that have only one nourishment scheduled)

BEACH FILL AND NEARSHORE FILL	PRE-FILL PLACEMENT	POST-FILL AS-BUILT	1^{st} THRU N^{th} YEAR*				LAST YEAR
			3 mo	6 mo	9 mo	12 mo	12 mo
BEACH: Profiles	X	X	X	X	X	X	X
Sediment	X	X	X	X	X	X	X
OFFSHORE: Profiles	X	X	X	X	X	X	X
Sediment	X	X	X	X	X	X	X
AIR PHOTOS	X	X	X	X	X	X	X
BIOLOGICAL Samples	X	X	X	X	X	X	X
WAVE DATA COLL.	Continuous						

* All sample times referenced after completion of post-fill as built survey.

BORROW AREA			AFTER EACH DREDGING	
SEDIMENT: Cores	X			X
Surface Samples		X	X	
BIOLOGICAL Samples	X	X	X	X
SUB-BOTTOM PROFILE	X			X

Table 5 (Continued)
SAMPLING SCHEDULE FOR BEACH FILL MONITORING
(For projects that have only one nourishment scheduled)

BEACH FILL AND NEARSHORE FILL	PRE-FILL PLACEMENT	POST-FILL AS-BUILT	FIRST YEAR			
			3 mo	6 mo	9 mo	12 mo
BEACH: Profiles Sediment	X X	X X	X X	X X	X X	X X
OFFSHORE: Profiles Sediment	X X	X X	X X	X X	X X	X X
AIR PHOTOS	X	X	X	X	X	X
BIOLOGICAL Samples	X	X	X	X	X	X
WAVE DATA COLL.	Continuous					

BEACH FILL AND NEARSHORE FILL	SECOND YEAR				THIRD YEAR		FOURTH
	3 mo	6 mo	9 mo	12 mo	6 mo	12 mo	12 mo
BEACH: Profiles Sediment	X X	X X	X X	X X	X X	X X	X X
OFFSHORE: Profiles Sediment	X X	X X	X X	X X	X X	X X	X X
AIR PHOTOS	X	X	X	X	X	X	X
BIOLOGICAL Samples	X	X	X	X	X	X	X
WAVE DATA COLL.	Continuous						

BORROW AREA SAMPLING SCHEDULE			
	PRE-DREDGING	POST-DREDGING	LAST YEAR
SEDIMENT: Cores Surface Samples	X 	 X	X
BIOLOGICAL: Samples	X	X	X
SUB-BOTTOM PROFILING	X		X